Our global environment consists of numerous natural and artificial metals. Metals have played a critical role in industrial development and technological advances. Most metals are not destroyed; indeed, they are accumulating at an accelerated pace, due to the ever-growing demands of modern society. A fine balance must be maintained between metals in the environment and human health. Many metals are of concern because of their toxic properties and some metals are also essential for survival and health of animals and humans. The heavy metals, including lead, cadmium, and mercury are well recognized as toxic substances in the environment.

Global water pollution is because of the production of gallons of wastewater from various industries. The water running out of such industries not only contains organic pollutants but also heavy metal ions. However, their discharge into the environment by a number of industries include mining, electroplating, metal finishing, paints, pigments, textile, cement, nuclear and electronic, are the major causes of water pollution and gives rise to anomalously high concentration of the metals relative to the normal background levels [1-3].

Unlike toxic organic compounds, heavy metals are totally non-degradable and hence they tend to accumulate in the environment [1]. Heavy metals are among the conservative pollutants that are not subjected to bacterial attack or other break down or degradation process and are permanent addition to the aquatic environment. Hence they find way up in the food pyramid. When they accumulate in the environment and food chains, they can profoundly disrupt the biological processes [4, 5].
Because of their detrimental effects on living species the abatement of heavy metal is extremely important.

Widespread concern over the cumulative toxicity and environmental impact of heavy metals has led to an extensive research on the development of alternative technologies for the removal of these heavy metals from the effluents and industrial wastewaters.

Numerous processes are available for removing dissolved heavy metals, including precipitation and ion exchange. Out of which precipitation and ion exchange are the two removal techniques that have found wide applications. Precipitation of heavy metal ions with calcium hydroxide is a conventional method of removing heavy metals from wastewater [6]. However, these methods require the use of chemicals and synthetic resins which are expensive [7]. There has been increasing interest in introducing living bacteria and algae for the bioremediation of heavy metals from aqueous streams [8]. Commercial applications of this research are still hampered by the cost of growing pure cultures of cells and microorganisms and by the need for their immobilization or separation from the aqueous stream [9]. Also, the rhizofiltration [10], reverse osmosis, electrodialysis [11], phytoremediation [12], electrocoagulation [13], electrodeposition [14] and electrowinning [15] techniques are successfully employed to decrease the contamination level. However these processes are hampered, especially when the solutions containing heavy metals in the order of 1-100 mg per liter [16]. Safe and effective disposal of heavy metal-bearing wastewater is a difficult task due to the fact that cost-effective treatment alternatives are not available.

Adsorption phenomena have been known to mankind for a very long time, and they are increasingly utilized to perform desired bulk separation or purification purposes. Adsorption on activated carbon is considered to be a particularly competitive
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and effective process for the removal of heavy metals in trace quantities. However, the use of activated carbon is not suitable in developing countries due to high cost associated with the production and regeneration of spent carbon [17, 18]. Due to this problem, some researchers have diverted their research interest to identify other alternative adsorbents, especially to remove heavy metals from aqueous solution. The materials developed for this purpose range from industrial wastes to agricultural waste products, and the use of various substances such as activated coconut shell carbon [19], clay-iron oxide magnetic composite [20], mango peel waste [21], functionalized silica [22], zeolites [23], hydroxides [24], fertilizer industry waste material [25], diatomite [26], Biomass [27], synthetic polystyrene resin [28] and so forth have been exploited. Still the extent of uptake of heavy metals by these materials is not desirable.

In recent years, the new promises that nanotechnology offers have spurred the industries to focus their research and investments on developing new applications such as purification of air, water and hazardous waste [29]. Nanoparticulates have much larger surface areas than bulk materials and exhibit novel properties due to their small size. In recent years, variety of nanomaterials such as carbon nanotubes [30], TiO₂ [31], magnetic chitosan nano composite [32], magnetic Fe₃O₄ [33], surface modified MnFe₂O₄ [34], alumina [35], have been investigated for their tendency towards the removal of toxic metals. Although research in the area of heavy metal removal by nanomaterials is underway, very little attention has been dedicated to this important issue.

The present work is mainly focused on the preparation of low cost metal oxides and hydroxides for the removal of heavy metal ions such as Cr(VI), Cu(II), Zn(II), Pb(II), Cd(II) and Hg(II) from waste water. These metal oxide and hydroxide nanoparticulates can exhibit an array of unique novel properties such as large surface
area, high specificity, good reactivity and other properties, which can be an added advantage for the removal of heavy metals from wastewater.

The thesis entitled “Preparation of nanoparticulate metal oxides and hydroxides and their application in the removal of toxic heavy metal ions from wastewater” comprises 9 chapters.

Chapter-1 deals with the general introduction on various features of water pollution and different methods adopted for the treatment. Also it covers the applications of different nanomaterials towards the removal and detection of heavy metal ions in wastewater.

Chapter-2 outlines the broad aim and scope of the work. It highlights the importance and comprehensive approaches to the role of adsorption including detection of heavy metal ions in aqueous medium.

Chapter-3 gives the methods and materials adopted for the studies. This includes:

- Preparation of metal oxides and hydroxides nanoparticulates.
- Structure and surface morphology studies of prepared nanoparticulates using X-ray diffraction and Scanning electron microscopic techniques.
- Evaluation of the optimum adsorption conditions such as concentration, equilibrium time and temperature on the removal efficiency of different nanoparticulates towards the given metal ion.
- Evolution of thermodynamic and kinetic parameters.
- Preparation of modified carbon paste electrode for the detection of heavy metal ions.
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The voltammetric and spectroscopic studies using modified electrodes.

Chapter-4 presents the preparation and characterization of metal oxides \([\text{ZnO, CuO, NiO}]\) and hydroxides \([\text{Zn(OH)\textsubscript{2}, Cu(OH)\textsubscript{2} and Ni(OH)\textsubscript{2}}]\). The effect of surfactants on the size and structure of the metal oxide nanoparticles was studied.

Chapter-5 pertains the adsorption studies for the removal of \(\text{Cr(VI)}\) and \(\text{Cu(II)}\) ions using \(\text{ZnO, CuO, NiO, Zn(OH)\textsubscript{2}, Cu(OH)\textsubscript{2} and Ni(OH)\textsubscript{2}}\) nanoparticulates in aqueous medium. The batch mode of adsorption was employed to evaluate the adsorption efficiency of the different adsorbents.

Chapter-6 focuses on the adsorption studies for the removal of \(\text{Pb(II), Cd(II), Zn (II)}\) and \(\text{Hg(II)}\) ions using \(\text{ZnO, CuO and NiO nanoparticulates.}\

Chapter-7 reports the results and discussions for the detection of \(\text{Pb(II), Cd(II) and Hg(II)}\) ions using oxides modified carbon paste electrodes.

Chapter-8 describes the results and discussions for the detection of \(\text{Pb(II), Cd(II) and Hg(II)}\) ions using alkaline earth metal phosphates (barium phosphate and strontium hydrogen phosphate) modified carbon paste electrodes.

Chapter-9 outlines the main conclusions of the work.
References